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ATOMIC OXYGEN

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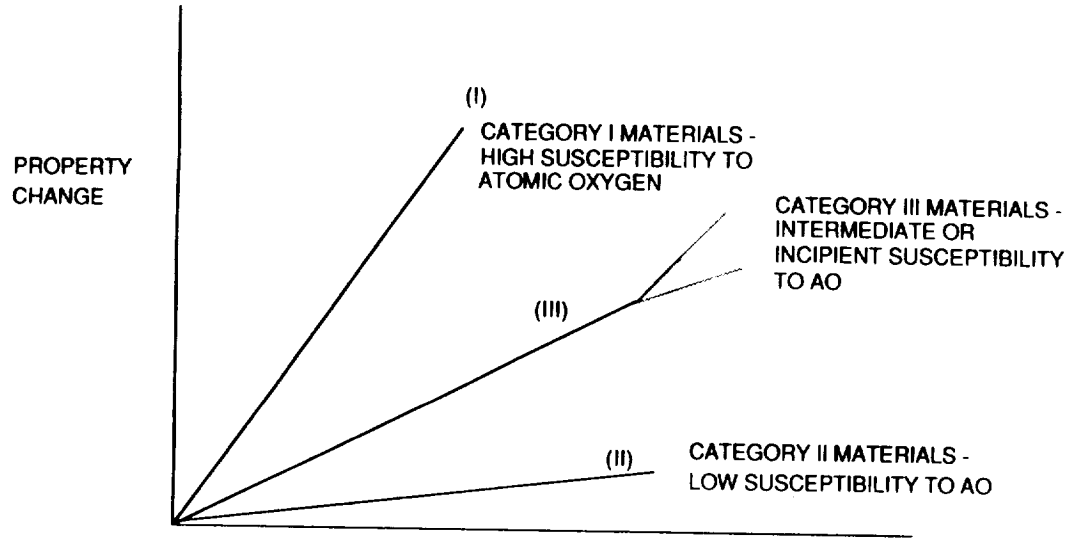
MATERIAL PERFORMANCE CATEGORIES



WHAT MATERIALS ARE MOST VULNERABLE TO ATOMIC OXYGEN DEGRADATION?

- CATEGORY I AND III MATERIALS ARE MOST VULNERABLE; CATEGORY II MATERIALS ARE LEAST VULNERABLE
  - FOR SOME APPLICATIONS, EVEN SMALL DEGRADATION DUE TO AO INTERACTIONS MAY BE UNACCEPTABLE
  - MOST SENSITIVE ORBITS ARE THOSE LEO ORBITS WHERE AO NUMBER DENSITIES VARY BETWEEN 10^5 - 10^9 ATOMS/CM ^{3}
    - DEGRADATION EFFECTS VARY IN RELATION TO EXPOSURE TIME (FLUENCE)
    - MATERIAL APPLICATIONS AND SYSTEM PERFORMANCE REQUIREMENTS DETERMINE EXPOSURE CONDITIONS
  - PROLONGED EXPOSURE OF SENSITIVE MATERIALS WILL RESULT IN DEGRADED SYSTEM PERFORMANCE OR REQUIREMENTS FOR ON-ORBIT MAINTENANCE; BOTH CONDITIONS CONTRIBUTE TO INCREASED MISSION COST AND REDUCED MISSION OBJECTIVES

MATERIAL CLASSES FOR SPACECRAFT APPLICATIONS

MATERIAL CLASS	PERFORMANCE CATEGORY
• ORGANIC FILMS	I-II
• INORGANIC	II
• SILICONE PAINTS	II
• LUBRICANTS	I-II-III
• ORGANIC ADHESIVES	I
• ORGANIC COMPOSITES	I
• METAL MATRIX COMPOSITES	II
• THERMAL CONTROL COATINGS	I-II-III
• OPTICAL COATINGS	I-II-III

C-3

SPACECRAFT ORBITS SENSITIVE TO AO INTERACTIONS

- MINIMUM ALTITUDE IS 100 KM
- MAXIMUM ALTITUDE IS 700 KM, ALTHOUGH VERY SENSITIVE SYSTEMS MAY BE AFFECTED AT HIGHER ALTITUDES
- WHY? -- OXYGEN ATOM CONCENTRATIONS ARE DOMINANT WITHIN THESE ALTITUDE RANGES

CORRELATION OF AO EFFECTS ON MATERIALS

- LABORATORY AND FLIGHT EXPERIENCE REPRESENT RELATIVELY IMMATURE DATA BASE
  - FLIGHT DATA LIMITED IN FLUENCE AND ACCURACY OF FLUENCE ESTIMATES
  - LABORATORY SIMULATIONS ONLY RECENTLY AVAILABLE
  - QUALITATIVE CORRELATION OF LABORATORY AND FLIGHT DATA FOR VERY LIMITED NUMBER OF MATERIALS (REACTION EFFICIENCIES AND MORPHOLOGY CHANGES, ACTIVATION ENERGY)
- FUTURE FLIGHT EXPERIMENTS TO PROVIDE ACCURATE REACTION RATE MEASUREMENTS FOR COMPARISON TO GROUND-BASED RESULTS

CORRELATION OF SPACECRAFT GLOW EFFECTS

- CORRELATION BETWEEN GLOW FLIGHT EXPERIMENTS AND LABORATORY RESULTS
  - VISIBLE EMISSIONS
    - = MEASURED SPECTRUM SIMILAR TO LABORATORY NO_2
    - = PREDICTED PHENOMENA VERY DIFFICULT TO SIMULATE
    - = EFFECTS OF SURFACE PROPERTIES ON RECOMBINATION EFFICIENCY (INCLUDING STICKING EFFICIENCIES VS T_S) NEEDS STUDY
  - UV EMISSIONS
    - = MEASURED SPECTRUM (1400-1800) SIMILAR TO LABORATORY SURFACE RECOMBINATION (N_2 -LBH)
    - = NO GOOD FLIGHT UV DATA BASE
    - = PREDICTED PHENOMENOLOGY (1-5 EV N_2 ON SURFACE) HAS NOT BEEN DONE
  - IR EMISSIONS
    - = FLIGHT DATA SPARCE
    - = LABORATORY EXPERIMENTS OF MANY PREDICTED PHENOMENA CAN BE SIMULATED

DO WE KNOW ENOUGH TO LAUNCH FOR 10-30 YEARS OF SERVICE WITH CONFIDENCE?

- NO FLIGHT OR LABORATORY DATA BASE FOR FULL LIFE EXPOSURE; LIMITED EXPOSURE ONLY
- MATERIALS ARE AVAILABLE THAT APPEAR TO BE NON-REACTIVE TO AO
  - LIMITED KNOWLEDGE PLACES SEVERE CONSTRAINTS ON SYSTEM DESIGN
  - EACH APPLICATION REQUIRES SPECIAL CONSIDERATIONS AND UNDERSTANDING OF SYNERGISTIC EFFECTS
  - DESIGN SOLUTIONS FOR 5-YEAR LIFE HAVE BEEN DEVELOPED
  - ACCELERATED, FULL-LIFE TESTING OF PROTECTIVE COATING CONCEPTS TO BE CONDUCTED IN GROUND-BASED LABORATORIES
- SYNERGISTIC EFFECTS NOT ADEQUATELY UNDERSTOOD

ARE TERRESTRIAL LABORATORY FACILITIES ADEQUATE?

- AT LEAST TWO AO-BEAM FACILITIES HAVE ADEQUATE SIMULATION CAPABILITY

	STRENGTHS	WEAKNESSES
PHYSICAL SCIENCES CORP.	• LARGE BEAM (30-1,000 CM^2) • MULTIPLE SAMPLES • HIGH ENERGY (5-12 EV) • LONG EXPOSURES POSSIBLE • HIGH FLUX (10^{18} - 10^{16} ATOMS/CM^2) • FLUENCE UP TO 10^{21} ATOMS/CM^2 HAVE BEEN ACHIEVED	• PULSED SOURCE • HIGH INSTANTANEOUS FLUX
LOS ALAMOS	• CONTINUOUS BEAM • HIGH ENERGY (1-5 EV) • HIGH INTENSITY (10^{17} ATOMS/CM^2) • LONG EXPOSURES (76 HRS) • FLUENCES TO 2 X 10^{22} ATOMS/CM^2 HAVE BEEN ACHEIVED	• SMALL BEAM • CONTAINS O_2 , INSERT GAS, 0° AND UV

- OTHER FACILITIES BEING DEVELOPED
- NEED TO PROVIDE HIGH QUALITY SIMULATION FACILITY TO COMMUNITY FOR MATERIAL EVALUATIONS

SYNERGISM WITH OTHER FACTORS

- SYNERGISM WITH OTHER FACTORS IMPORTANT RELATIVE TO MATERIAL EFFECTS
- MOST IMPORTANT APPEAR TO BE DAMAGE TO PROTECTIVE COATINGS FOLLOWED BY REACTION WITH SUBSTRATE
  - RADIATION INDUCED FAILURE OF COATING
  - MICROMETEOROID/SPACE DEBRIS (SMALL PARTICLES)
  - THERMAL CYCLING
  - CHARGING DAMAGE
- ACCELERATION OF REACTION RATES
- GLOW SYNERGISM WITH OTHER FACTORS
  - SURFACE CONTAMINATION
  - GAS RELEASES OF REACTIVE PRODUCTS
- HAS SYNERGISM BEEN TESTED OR EVALUATED?
  - INITIAL CONSIDERATION OF COUPLING, BUT VERY LIMITED EVALUATIONS
  - LABORATORY FACILITIES WITH COMBINED ENVIRONMENTS NOT AVAILABLE

NEED FOR SPACE EXPERIMENTS

- SPACE EXPERIMENTS ARE NEEDED FOR MATERIAL INTERACTION ASSESSMENT
  - VALIDATION OF GROUND-BASED MATERIAL EVALUATION SYSTEMS
  - ESTABLISH MATERIAL REACTION DATA BASE
  - ENHANCED UNDERSTANDING OF INTERACTION MECHANISMS LEADING TO CONFIDENCE IN DESIGN
- GLOW SPACE EXPERIMENTS ARE NEEDED
  - ESTABLISH DATA BASE ON GLOW CHARACTERISTICS ACROSS SPECTRAL REGIONS OF INTEREST
  - VALIDATED EXISTING MODELS

PROPOSED EXPERIMENTS

- LDEF RETRIEVAL
  - EXPANSION OF DATA BASE
  - HIGH FLUENCE EXPOSURE (1×10^{21} ATOMS/CM^2)
  - FLUX EFFECTS (LOW FLUX OVER LONG EXPOSURE)
  - HARDWARE ASSESSMENTS
- EOIM-3
  - BENCHMARK REACTION RATE DATA BASE USING ON-BOARD MASS SPECTROMETER
  - DATA FOR CORRELATION WITH GROUND SIMULATION SYSTEMS
- DELTA STAR
  - ACTIVE SENSOR DEVELOPMENT AND PERFORMANCE ASSESSMENT
  - CORRELATION WITH GROUND-BASED SIMULATION FACILITIES
- SMALL SATELLITES (INCLUDING LDEF)
  - ORIENTATION CONTROLLED
  - REAL TIME DATA
  - RECOVERY (IN SOME CASES)
  - DEPLOY IN DIFFERENT ORBITS INCLUDING HIGH ALTITUDE, LONG EXPOSURES

PROPOSED EXPERIMENTS (CONTINUED)

- LDEF REFLIGHT
  - REAL TIME TELEMETRY DATA
  - EVALUATE ADVANCED MATERIAL CONCEPTS
- SATELLITE RETRIEVAL
  - RECOVERING EXISTING SATELLITES FOR POST-MISSION INSPECTION
  - SATELLITE ORBITS MAY NOT BE COMPATIBLE WITH STS MISSIONS--MAY REQUIRE SPECIAL PROVISION FOR SHUTTLE RECOVERY
- SPACECRAFT GLOW
  - NASA OAST OUTREACH EXPERIMENT
  - INFRARED GLOW MEASUREMENTS
  - CIV GLOW EFFECTS
- DEVELOPMENT OF LOW-COST SATELLITE BASE AND ACTIVE SENSORS

EXPERIMENT CHARACTERISTICS

- MATERIAL EFFECTS EXPERIMENTS
  - LONG DURATION EXPOSURES
  - CONTROLLED SPACECRAFT ORIENTATION
  - DISTURBANCE INDEPENDENT
  - PROVISIONS FOR ELECTRICAL POWER
  - TELEMETRY
  - GOOD CONTROL OF CONTAMINATION
- GLOW INVESTIGATIONS--SAME REQUIREMENTS AS MATERIAL EFFECTS, EXCEPT:
  - ELLIPTICAL ORBITS
  - LONG DURATION DURATION EXPOSURES NOT NECESSARY

VOLUME, WEIGHT, AND COMPLEXITY OF EXPERIMENTS

- MATERIAL EXPERIMENTS

- EOIM-3	- WEIGHT--1,000 LBS, WITH STS CARRIER - VOLUME--1/8 SHUTTLE PAYLOAD BAY - COMPLEXITY--MODERATE COMPLEXITY (RAM ORIENTATIONS REQUIRED)
- LDEF	- PREVIOUSLY DESCRIBED
- DELTA STAR	- WEIGHT--50 LBS - VOLUME--SEVERAL CUBIC FEET - COMPLEXITY--LOW (ACTIVE TRAY)
- SPACECRAFT GLOW	- WEIGHT--1,000 LPS, WITH STS CARRIER VOLUME - 10 CUBIC FEET